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ABSTRACT

This paper examines the classroom-based research carried out by a full-time mathematics teacher who monitored what was happening to his class of 13-year-old students as they were engaged in a collaborative, peer interactive classroom environment and examined how this environment influenced, and was influenced by, the students' attitude toward mathematics. An attempt was made throughout the school year to take into account the students' background knowledge and to frequently survey the students for their assessment of the classroom environment. By the end of the implementation, the students were more active participants in their own mathematics learning and culture than they had been at the beginning of the year. Observations from this study illustrate the social outcomes that developed in the students, such as listening, caring for the progress of others, providing help and guidance, negotiating explanations and solutions into a group consensus and peer teaching. Findings also demonstrate that the teacher had progressed towards a more socio-cultural constructivist approach in his teaching. Contains 115 references. (Author/MKR)

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Abstract

This paper examines the classroom based research carried out by Dennis, a full time mathematics teacher, who monitored what was happening to his class of 13 year old students as they were engaged in a collaborative, peer interactive classroom environment and examined how this environment influenced, and was influenced by, the student's attitudes to mathematics.

Multiple theoretical frameworks influenced the design of this study. Socio-cultural, constructivist and Vygotskian perspectives were all considered, for it was the emergent rationalised combination of all these perspectives which defined and framed the approach adopted and applied by the authors. In this study, a classroom environment was established based on the negotiated social norms of the teacher and the students and involved considerable discussion, negotiation and consensus seeking by the class. The students worked in collaborative groups on the standard first year high school mathematics course as used at Dennis's school. An attempt was made throughout the year to take into account the students' background knowledge and to frequently survey the students for their assessment of the classroom environment. By the end of the implementation the classroom operated on a basis where the students were more active participants in their own mathematics learning and culture than they had been at the beginning of the year. Observations from this study illustrate the social outcomes that developed in the students such as listening, caring for the progress of others, providing help and guidance, negotiating explanations and solutions into a group consensus and peer teaching. Findings also demonstrate that Dennis had progressed towards a more socio-cultural constructivist approach in his teaching and produced in him a developing realisation that the future reality for the education of our students is that of teaching them about learning to learn in a socially diverse and culturally mixed global community.

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Introduction

This paper reports on a study of the implementation of a particular teaching and learning environment in a typical Australian high school mathematics classroom (Malone & Ireland, 1993). The focus was on creating a socio-cultural teaching and learning classroom environment within which a group of students, 21 girls in their first year of secondary school, would learn mathematics (van der Veer & Valsiner, 1991).

This study involved developing in Dennis and his students an awareness of the roles of social and cultural interactions found in the learning environment (Perret-Clermont, 1980; van Lieshout, 1987; Rogoff & Lave, 1984; Cobb, Wood & Yackel, 1990; Tudge, 1990). To this end the students were engaged in a collaborative, peer interactive classroom environment which involved them in jointly working on solutions to problems (Vygotsky, 1978; Griffin & Cole, 1984; Schoenfeld, 1985; Stallings & Stipek, 1986; Bennett & Cass, 1990; Rogoff, 1990; Burbules & Linn, 1991; Linn & Burbules, 1993). Dennis, the teacher in this study and co-author of this paper, wanted to see how a Vygotskian framework functioning effectively within the normal routines of school life (Rogoff, 1990; Steedman, 1991; Cobb, Wood & Yackel, 1991) would benefit his teaching and his students' learning of mathematics (Pope, 1991).

Certain aspects of a social constructivist approach to teaching (Lerman, 1989; Davis, Maher & Noddings, 1990a; Doise, 1991; Steffe, 1991; Tobin, 1990; Davis, Maher & Noddings, 1990b) were also adopted in order to merge the ethnographic methodology (Vasta, 1982; Goetz & LeCompte, 1984; Erickson, 1986) of action research (Nixon, 1981; Rowland, 1986; Oja & Smulyan, 1989; Kinchloe, 1991; Altrichter, 1993) with the theoretical paradigms of Vygotsky (Moll, 1990; Pontecorvo, 1990; Vasta, Haith & Miller, 1992). Using a multiple framework approach accommodated all of the facets which interplayed on the design of this classroom based study and suited the teaching style Dennis had determined to use in order to effectively implement a socio-cultural environment.

Viewing the outcomes of this study from a socio-cultural constructivist perspective highlights the importance of the learners developing social norms for use in the environment (Rogoff, 1990), reflecting on their work, collaborating with peers, negotiating meaning through discussion (Huber 1990; von Glasersfeld, 1991; Lochhead, 1991), arriving at consensus and accounting for the background knowledge each student brings to class (Baroody & Ginsburg, 1991; Cobb et al., 1991).

The importance of the cultural impact upon the classroom is one focus of the recently published National Statement on Mathematics for Australian Schools (Australian Education Council [AEC], 1990, p. 6-7). For students, activities such as playing and explaining, along with counting, measuring, locating and designing have been identified as probably universal in the development of mathematical ideas in different cultures. However, while mathematical thinking is part of the cultures of origin of all Australians, we may not all interpret basic conceptions in the same manner (AEC, 1990, p. 6-7).

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The aim of the environment which Dennis developed in this study was to bring out and capitalise on aspects of the cultural diversity in the students' backgrounds and to provide the students with a non-threatening learning environment. Adopting a Vygotskian perspective using peer interaction in a collaborative environment presented the vehicle through which this aim could be achieved and it had the effect of making the classroom mathematics more familiar to the students as they developed their understanding of the international 'body of knowledge' of mathematics which has resulted from the convergence of the mathematical activities of many cultures over time (AEC, 1990, p. 6-7).

Theoretical Background

Socio-cultural, constructivist and Vygotskian perspectives framed the multiple theoretical stance which influenced the design and approach taken by the authors in this study. In examining these perspectives Dennis merged the influences of Vygotsky's socio-cultural theories of development (Campione, Brown, Ferrara & Bryant, 1984; Wertsch, 1991) with the practicalities of contemporary socio-culturalism and the applicability of several aspects of constructivism (Lerman, 1989).

Dennis found himself in the position of formulating this study along the paradigmatic lines of socio-culturalism but in such a way that it was clearly influenced by all he had read about constructivism. This required him to make a shift in his perspective from the teacher who stands in front of the classroom and simply teaches to one who tries to facilitate learning, a position aligned somewhat to a constructivist perspective. Such a position may seem untenable to some but it proved to be highly functional and theoretically acceptable as Cobb (1994) illustrates when he questions assumptions that give rise to a forced choice between constructivist and socio-cultural perspectives and contends that the two perspectives can be viewed as complementary, with each constituting the background against which the other comes to the fore.

If we view learning as a process of acculturation then we take a socio-cultural perspective. This is closest to the approach adopted by Dennis in his teaching. The constructivist view focuses on the distinct interpretations of the individual students and their interests in striving to make sense of the classroom events (Cobb, 1994). Dennis also adopted aspects of this approach in his teaching. A socio-cultural theorist might view classroom interactions as the culturally organised practices of schooling, whereas a constructivist would see an evolving microculture unable to exist beyond the teacher's and students' attempts to achieve intersubjectivity in their individual activities. A socio-cultural theorist might also see a student appropriating the teacher's contributions, whereas a constructivist would see a student adapting to the actions of others through the process of negotiation (Cobb, 1994, p. 15). The students in this study were influenced by the teacher (Dennis) and by each other in both group and whole class activities. Teachers as practitioners would agree with aspects of both sides of these arguments, as does Dennis, but he aligned himself more with the socio-culturalists.

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In adopting a Vygotskian framework upon which to structure classroom interaction Dennis sought to make the students active participants in their leaning. By acknowledging students' background and cultural differences as well as their prior experiences and by emphasising discourse and intersubjectivity in the class it was anticipated that the students would develop enhanced positive attitudes. A Vygotskian approach allowed us to view learning as a process of acculturation involving the fulfilment of certain obligations to the school as a social institution and to a wider society and this also reflected our socio-cultural position (Cobb et al., 1990, p. 137; Tudge, 1990). Such an approach is frequently utilised within different research paradigms to study how social interaction, either with an adult or with peers, can enhance different types of learning. Peer interaction seemed to Dennis a valid description of the pedagogical process and providing the students with a non-threatening learning environment gave Dennis the opportunity to develop and maintain positive student attitudes to mathematics. Utilising peer interaction in a collaborative environment presented the vehicle through which this aim could be achieved.

Adopting a Vygotskian approach within which to form the teaching and learning environment offered Dennis the most comprehensive account of the link between development and instruction which he saw as central to an understanding of school learning (Pontecorvo, 1990, p. 3). Vygotsky argued, that instruction plays an extremely important role in development and he emphasised, in the process of teaching-learning, the assistance offered by a more competent "other" as learning progresses through what he called the zone of proximal (or next) development (Vygotsky, 1987, p. 211). Rogoff and Wertsch (1984) described the zone of proximal development as "the phase in development in which a child has only partially mastered a task but can participate in its execution with the assistance and supervision of an adult or more capable peer". Working on only partially mastered tasks and doing so successfully because of the help of others was to become "normal" practice in Dennis's classroom. This matches Vygotsky's thoughts on the role of learning which he saw as awakening a variety of internal developmental processes that are able to operate only when the student is interacting with people in his environment and in cooperation with his peers (Vygotsky, 1978, p. 90).

Undoubtedly part of the reason for the popularity of Vygotsky's theory lies in its fit with contemporary ideas about the importance of social factors and contexts in explaining student's behaviour (Vasta et al., 1992). Interactive learning situations that provide structured guidance for the learner and that operate within a collaborative environment to achieve the desired learning outcomes fit within a Vygotskian framework (Campione et al., 1984). To this end the students in this study were engaged in a collaborative, peer interactive environment involving groups jointly working out solutions to problems in their mathematics class (Linn & Burbules, 1993).

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In describing the Vygotskian, constructivist and socio-cultural perspectives which framed this study we have explicitly acknowledged the design behind our interpretive activity and have illustrated our awareness of the particular reasons why we adopted such a position. Cobb argues that ways of coordinating perspectives should be developed (Cobb, 1994, p. 19) and this study illustrates our way of so doing as we considered the issues to be addressed and our perspective with regard to those issues. We believe, as does Cobb, that each perspective needs to acknowledge the potential positive contributions of the other perspective (Cobb, 1994, p. 18). The social context of learning, while of recent interest to educational researchers, has always been at the forefront of the teaching process. Classrooms which encourage learning as a social process are needed as is a willingness and ability to work collaboratively with others and value their contribution (AEC, 1990 ; National Council of Teachers of Mathematics [NCTM], 1989).

In combining these perspectives this study aimed to establish itself as the practical implementation of a collaborative, peer interactive learning environment which was responsive to student perceptions of its functioning, and one which was effective in creating a classroom which reflected the socio-cultural norms of the students and teacher.

Methodology

Duration:

The longitudinal design chosen for this study facilitated the development of stable working relationships among the students (Forman & Cazden, 1985, p. 331). Dennis implemented this study for the full school year in an attempt to minimise one of the main problems in teaching-learning research namely, that researchers tend to overlook how most of the results of classroom teaching and learning are influenced by continuous and long-term processes (Achtenhagen, 1990, p. 647). Soviet research studies which, in the main, avoid the short clinical studies typical of most Western research preferring to examine instruction as it occurs in school settings over extended periods of time, often an entire academic year, also influenced this decision (NCTM, 1980).

Student collaboration:

Research in mathematics education lists many benefits evident in collaborative learning environments (Davidson & Kroll, 1991, p. 363). These benefits include: increased knowledge or skills, increased conceptual understanding, improved attitudes or motivation, improved communication skills, improved social skills, enhanced self-esteem, increased efforts to achieve, and ability to take the perspective of another person. In addition to these Kyriacou and Newson, (1991, p. 44), highlight such benefits as giving students a marked degree of responsibility to control and organise their work, being more able to sustain effort & concentration, finding such work fun and enjoyable, and providing a non-threatening atmosphere. The students in this study were engaged in a collaborative, peer interactive environment where, in small groups, they shared ideas and worked together to complete academic tasks (Davidson & Kroll, 1991, p. 362).

By working with others, students can communicate their ideas about mathematics while listening to and making sense of the ideas of others (Gadanidis, 1994, p. 94). This and other requirements such as the defence, interpretation and communication of findings and by the personal construction and reconstruction of knowledge, typify a social constructivist approach to the teaching learning environment (Parker, 1992, p. 28). The approach used in this study attempted to meet these requirements, not because of any loyalty to constructivism but rather as necessary procedures for the effective implementation of a collaborative and socially aware learning environment. The most significant requirement of working in a collaborative learning environment is the need of students for opportunities to make sense of what is learned by negotiating meaning. Negotiation in a classroom involves discussion and attentive listening, making sense of other's points of view, and comparing personal meanings with those of peers (Tobin, 1990, p. 32).

As the students are already active participants in social practice, they are able to engage in and contribute to the development of classroom mathematical practices such as discussion, negotiation and consensus as they develop their own understandings of the mathematics being studied. Through participation, the student functions with shared understanding although their use of this shared understanding is not the same as what was constructed jointly. It is an appropriation of the shared understanding by each student that reflects his or her individual understanding (Rogoff, 1990, p. 195). In most instances students prefer to work with others rather than alone, (Higgins, 1992, p. 2; Corsaro, 1985), and so collaborative learning capitalises on the powerful influence of peer relationships and can develop behaviours which lead to peer approval and group success (Artzt & Newman, 1990, p. 448). This involves taking advantage of the students' already social nature, their prior experiences and the fact that collaborative learning taps a natural, childlike curiosity for life and the fascination and wonder of learning (LaCombe, 1992, p. 7).

By adopting a collaborative learning technique for this study it was hoped to develop greater understanding about the value of such an environment which is far from that used for traditional classroom organisation (Forman & Cazden, 1985, p. 329). The collaboration was not to be restricted to group work however, as class consensus was also considered important. For Vygotsky, participation in activity, which is social in both senses, was the starting point in explaining the development of human consciousness. The students' activity is social in two ways. It is socio-culturally defined, and the student's experience involves social activity in the sense that he or she participates in "localised collectives", that is, concrete social interactional settings involving others. These combine in a student's experience when he or she participates in joint activity with more capable peers or adults who typically define and regulate the joint activity in accordance with socio-cultural patterns. Hedegaard, (1990, p. 369-370), found that it is actually possible to make a class function actively as a whole through class dialogue and collaborative group work. Hedegaard's teaching experiment also differed from traditional instruction in that the students were constantly and deliberately forced to act, and a similar approach was adopted in this study where the students monitored each others activity within their groups to ensure that each student participated as much as was possible in the activities.

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Research in the classroom:
Vygotsky himself was most concerned with instruction in school (Rogoff & Wertsch, 1984, p. 4) but many studies imply one-on-one interactions or at the most one small group to the teacher interaction and are probably, in the main, reporting on 'laboratory' type research, as distinct from 'classroom' type research. Lerman purports that theories and concepts are rooted in practice and obtain their meaning from their use (Lerman, 1989, p. 211 - 223). The theories Vygotsky expounds need to be applied to "real" 20:1 student-teacher ratio situations as existed in this study. Unlike this study, Moll found that while several recent doctoral dissertations had highlighted Vygotsky's work, none had examined classroom teaching or applied Vygotsky's theory in instruction (Moll, 1990, p. 2).

Taking the classroom as the laboratory is a practice often pursued by Soviet researchers (Kilpatrick & Wirszup, 1971, p. 1) although in the last few years the relation of research to practice is a matter which has been subjected to strong criticism, as investigations (if carried out at all) have been preformed primarily in laboratory settings and consequently their results have not matched adequately with the real-life conditions of education (Prucha, 1990, p. 668). Yet it is not just the adoption of Vygotskian perspectives that best situates this current research in the classroom. It seems important to test collaborative learning techniques in ordinary classrooms and in already existing courses, using simple procedures that can be easily duplicated by other teachers (Dees, 1991, p. 411). Research writings cannot on their own provide the practitioner with guidance as to the problems that they face on a day-to-day basis. It is apparent that if a transformation of classroom learning is to occur teachers need to construct local knowledge, addressing the problems they faced in the classroom. This implies that more relevant material will be found in the actual classroom where one teaches. Hence this study was based within the framework of a regular class taught by Dennis. The ultimate goal was to construct knowledge through observations of, participation in, and reflections about classrooms which then provided the basis for the transformation of classroom practice (Roth, 1993, p801).

Classroom environment:
To enabling the students to find, create and negotiate their meanings within the classroom required a collaborative learning environment. Dennis had been convinced by Vygotskian theory that peer interaction was valuable because of its potential to take advantage of the socio-cultural forces that students bring into the classroom. These forces subsequently made up the dominant socio-cultural learning environment of the mathematics classroom within which the students worked. Students are situated in many contexts, depending on their socio-cultural experiences, and so ways of enabling them to find, create and negotiate their meanings within the classroom are needed (Lerman, in preparation, p. 8). Being situated in many contexts was a factor in this study that determined which groups the students should be placed in and the structure of the ongoing classroom environment. The students involved in this study were those assigned to Dennis by his school to be one of his normal five classes, and the school's wide range of socio-cultural and academic background data was used to construct the groups (Webb, 1991). As far as learning mathematics (in the context of coming to terms with the taken-as-shared mathematics culture) is concerned, the students' classroom environment (of which the physical aspect only plays a minor part) is the main part of their socio-cultural experience within which that learning occurs.

Implementing a study such as this in an all girls school required the authors to consider classroom strategies which would enhance the mathematics for girls. Strategies such as using collaborative activities, including social and real life contexts in as many activities as possible and relating the content to girls' experiences and their future roles wherever possible (Department of Education, Employment and Training, 1992, p. 3). Other practices which were adopted included developing the sensitivity to know when to intervene to make suggestions to the groups and when to allow the students time to resolve conflicts themselves, balancing the tension between enhancing students' individual knowledge and their acculturation to the conventions of the wider society, and finding ways to extend and build upon the students' thinking (Wood, Cobb & Yackel, 1991, p. 610). There must come a stage when student ideas are extended and compared with other interpretations and meanings from other discourses (Lerman, in preparation, p. 10). This stage is easily provided for in the forum of the group. Here the student has the opportunity to extend and compare his or her ideas with those of others and to engage in considerable discourse among all class members to reach a consensus in the sense of a communal taken-as-shared understanding of the mathematics. In such an environment it is the role of the teacher to accept the students' ideas and work with them, build on them or help the class modify them as appropriate in order for all of the students to develop the accepted (even if only by the class) meanings.

Monitoring the environment:
The My Class Inventory or MCI (Fraser & Fisher, 1983) measures, which were taken in this study, enabled the students to regularly feedback their opinions on the collaborative, peer interactive learning environment within which they studied mathematics. The role of measuring the classroom environment was to give the students a voice in determining the success or otherwise of the implementation and was one of the unique features of this study. We must value and respect what the student knows not just because of constructivism but because doing so enhances the students' self esteem and self worth (Bickmore-Brand, 1993). By allowing students to have an input as to the workings of the environment you can, to a certain extent, accommodate the student's previous experience. The study of the classroom environment can contribute to the understanding of the social processes occurring within the classroom (Moos, 1979; Stern, 1970; Walberg, 1976) and the teacher can receive feedback about their students' perceptions and implement changes in accordance with the findings (Raviv, Raviv & Reisel, 1990, p. 142-143).

The teacher and the students together create the classroom social context, (Cobb et al., 1990, p137), so the teacher must arrange an environment in which the students are situated in such a way as to maximise the possibilities of the formation of ideas (van der Veer & Valsiner, 1991, p. 53). Findings from interventional research that introduces collaborative methods of instruction indicate that creating a classroom environment which allows the social nature of learning to be expressed, leads to increased learning (Tudge, 1990). Cobb (1994, p. 15) argues that neither an individual student's mathematical activity nor the classroom microculture can be adequately accounted for without considering the other which is another reason for making the environment a focus within this study especially as it is partly responsible for the development and potential modification of each student's present and future attitude to the subject.

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Hedegaard (1990, p. 84) intervened on existing classroom practices to reorganise the learning environment so that the students themselves could create a 'classwide' zone of proximal development. Creating an environment which allows a 'classwide' zone of proximal development to unfold was a primary aim of this study.

An action research approach:
This study had multiple frameworks influencing its design including awareness of socio-cultural facets to learning, aspects of constructivism for teaching, Vygotskian theoretical perspectives and the implementation of a collaborative, peer interactive learning environment for a period of one year in a 'normal' classroom (all girls) using the standard curriculum of the school. The first year high school mathematics course, as prescribed, was facilitated by working in collaborative, peer interactive groups and as a result the study did not impinge on the normal 'official' mathematics program, (Claffey, 1992; Cobb et al., 1991). Such a myriad of interplays required a highly reflective approach to this study and hence the dominant methodology chosen was an action research process utilising ethnographic techniques. This study was a "Study of Singularities" in that it takes account of the happenings in a single classroom. There is no attempt to generalise the findings beyond the classroom, but there is recognition that there may be aspects of the results which stimulate other teachers to try something similar (Bassey, 1986, p. 21). The results of interpretive research are of special interest to other teachers, who share similar concerns with the interpretive teacher researcher (Erickson, 1986).

Data Sources:

The dominant methodology used in this study was an action research process utilising ethnographic techniques. By admitting into the research frame the subjective experiences of both the students and the teacher, this study aimed to provide a depth of understanding lacking in similar approaches (LeCompte & Goetz, 1982, p. 32). One of the main problems in teaching-learning research is that researchers work with selected students or groups, and not with all the individuals in the class (Achtenhagen, 1990, p. 647). This study expands on this requirement since all of the students in the class were the focus of observation as individuals, as members of groups and as a class. In fact this study is more characteristic of observational research than ethnographic research (Evertson & Green, 1986).

One does not need special training to be able to understand the results of such research (Erickson, 1986). The best way to learn how to do ethnography is to do it (Gallagher, 1984). Such fieldwork based research requires skills of observation, comparison, contrast and reflections that all humans possess.

The school had a wide range of socio-cultural and academic background data from which the information to construct the groups could be drawn (Webb, 1991, p. 379). Such information tends to be richer at the point of entry to the school and has not been coloured by teacher perceptions of the students which tend to develop and exist after their first year in a school.

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Parental input was higher for these students through the standard use at the school of Year 8 parent information evenings and the 'natural' interest and concern of the parents for their children as they settle into their first year at high school (O'Connell, 1992, p. 12). Thus first year students, Year 8, were chosen as the research group for this study. They were new to the high school and therefore had very few set ideas on the way the class would operate and so were more accepting of the intended work environment (Midgley, Feldlaufer & Eccles, 1989, p. 988). More senior classes often prefer environments which they have become accustomed to or comfortable in and are therefore less accepting of any alternatives.

Triangulation in interpretive style studies such as this, is a technique which provides more and better evidence from which a researcher can construct meaningful propositions about the social world. Its value lies in providing evidence for explanations of the social phenomena observed (Mathison, 1988, p. 15). As Miles and Huberman (1984) suggest:

> ... triangulation is a state of mind. If you self-consciously set out to collect and double-check findings, using multiple sources and modes of evidence, the verification process will largely be built into the data-gathering process, and little more need be done than to report on one's procedures. (p. 235)

The data sources for this interpretive study include; collecting and analysing audio recordings of each days lessons, Dennis's daily field notes, his weekly and monthly summaries of the observations (Enright, 1981; Guba & Lincoln, 1982; Maher & Davis, 1990; Erickson, 1992); independent observations and individual student interviews by a teacher colleague who interviewed the students during several lessons focusing on specific issues that had arisen, asking set questions in all but the last couple of sessions when the students had the opportunity to say what they liked; photographs of the groups working and John's field notes and analysis notes on the direct observation and video recording of nine lessons each of which focused on some aspect of the environment which we wished to examine and was then reviewed shortly after recording.

Relevant student attitude and classroom environment measures were collected using the MCI surveys (AEC, 1990; Fraser, Malone & Neale, 1989; Fraser & Fisher, 1983; LeCompte & Goetz, 1982) and these were used to provide feedback on ways of improving the environment from the students perspective with the teacher and the students jointly discussing the outcomes of each survey. Subsequently the teacher would implement changes to the environment to more closely align it with the individual, group and class preferences.

In addition, questionnaires and class tests were collected to supplement the data, contribute to triangulation and help generalise interpretations (Eisenhart, 1988; Mathison, 1988). One such item was the 'buddy reports' which came from the placement of one student in a different group for one week who then supplied Dennis with a 'independent' report on aspects of that group's collaboration.

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The observations and interactions with the class occurred over the full school year helping to maintain a 'natural state' in the classroom (Gallagher, 1984). Some very rich data or information has come from some of the surveys the students have completed and they remained frank, open and honest about the class throughout the year.

The methodology used in analysing the data corpus involved the following procedure. Daily reports were summarised from each audio tape in combination with the daily field notes as soon as possible after the lesson, then weekly reports were summarised from each weeks set of daily audio notes and daily field notes. At the same time any special events that occurred during the week are written up such as a set of observers field notes, the analysis of an attitudinal survey or the review of a lesson on video tape and any test data collected throughout the week. Monthly reports were compiled after three or four weeks based on the weekly reports and developed in more of a 'story' style using themes to focus the observations (Carter, 1993, p. 8). A term review was written at the end of each school term to focus on the methodology of this study and examine the effectiveness of what had been achieved and what needed to be further developed in light of the aims of this study.

Findings: Observations from within a socio-cultural perspective

We start with the findings from the observations that have been made of this collaborative, peer interactive environment, taken from the perspective of the multiple frameworks which guided this study, and which support our conclusions regarding the success of the implementation of such an environment. Such a perspective gives importance to learners developing their social skills, reflecting on their observations, collaborating with peers, negotiating meaning and arriving at consensus. In addition this perspective requires the teacher and the students to take account of their own social experiences and those of others and value these as important contributions to their learning.

The following observations (*in italics*) relate to these, and other aspects of the students who were being studied. These statements are drawn from Dennis' daily diary (M1 = first monthly field notes review, M2 = second monthly field notes review, and so on).

Social aspects:

Social constructivism sees mathematics as both a cognitive activity constrained by social and cultural processes, and as a social and cultural phenomenon that is constituted by a community of individuals (Wood, Cobb and Yackel, in press). Such a view takes account of students' socially situated mathematical experiences and sees as complimentary the cognitive and social processes of the students. In our research we found that while the socio-cultural viewpoint guided our analysis we utilised some aspects of social constructivism as theoretical support for our approach.

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Students begin their mathematical experiences at home, (AEC, 1990), where they are active, social individuals making sense of the world through their communications with other people and this activity helps the students to clarify their thinking and sharpen their understandings (NCTM, 1989). Families are groups (Australian Association of Mathematics Teachers, 1992) and research suggests a view of mathematics classrooms that makes close contact with communication and social interaction, as emphasised in the NCTM Standards document (Research Advisory Committee of the NCTM, 1988), as well as with the socio-cultural context of mathematics education. By communicating and interacting socially the students open up their world to examination and see the world of others for comparison. Some examples from this study of the influences of this socio-cultural interaction follows.

- *The students have made comparisons between their mathematics and their Religious Education classes.* (M3)
- *The students talk to other students outside of the class which can result in discussion leading to re-negotiation, peer teaching or the resolution of a class based misconception.* (M4)

Vygotsky (1962) argued that students learn in social situations by initially imitating a more accomplished peer or adult in a collaborative social setting, and gradually take over the regulation of learning from the other person to solve the task for themselves. The findings of a study by Douglas and Sutton (1978) are regarded as supporting Vygotsky's theoretical assumption that the major impetus for student's development comes from the opportunity for interaction with supportive adults (Ireland, 1986). Every classroom can claim to fit such a model as the teacher is always a supportive adult. In this study such interaction between student peers and between the students and the teacher was constantly encouraged. One observation of the class being studied shows that things are not always as social as one might prefer.

- *Sometimes the students only interact when querying answers and correcting the teacher or negotiating or clarifying or checking answers or the marking procedure.* (M4)

We must value and respect what the student knows, not just because constructivism says we should, but because doing so enhances the students self esteem and so the teacher should attempt to shift the focus from his / her self to the student. Role change is important where the teacher becomes student and the student becomes teacher (Bickmore-Brand, 1993; Larsen & Pfitzner, 1993). This allows more peer interaction as everyone becomes a valued member and teacher within the class (Behounek, Rosenbaum, Brown & Burcalow, 1988). Teacher-student interactions in classroom roles are not always reversible, but in peer interaction, roles may be easily reversed, directions may be given as well as followed and questions both asked and answered. This places significant value on peer interaction in a student's development (Ireland, 1986). The class in this study enjoyed considerable success in enhancing the learning environment through teacher student role reversal and through peer interaction. This happened in many ways.

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- *Highlighting student methods and pointing them out to the class values student input.* (M5)
- *Several students offer advice, ideas, methods etc. to the other students so the teacher is not the only teacher.* (M6)

Reflection:

Students who work at problems in groups have to verbalise how they see the problems and what they intend to do about them. This is one way of generating reflection, which requires awareness of what one is thinking and doing (von Glasersfeld, 1993). Being clear on what you are saying, working from where you are at, indeed knowing what you know are all key issues for the student learning in an environment as was operating in this study. The following observations illustrate the variety of ways in which the students are assisted by reflecting on their work.

- *Having to demonstrate a concept to others on the board makes the students clarify their own ideas first.* (M1)
- *Asking students to explain their answers often leads to clarification of the students misconceptions.* (M1)

Such learning involves progress in developing and implementing new skills and being able to express these. An example is reminding a student to take a step that is understood. This is the preferred strategy because, as Wertsch (1979) points out, it encourages the shift from other regulation to self regulation which is the goal of collaborative work (Ireland, 1986). The teacher is constantly engaged in facilitating this shift as these observations show.

- *The teacher moves around among the groups, discussing their work, challenging their understandings, getting the students to clarify and express their ideas orally.* (M2)
- *The teacher encourages the students to use methods which are right and which work for them no matter how simple.* (M6)

Collaboration:

Soviet psychologists see students as taking an active part in learning, structuring their experiences and environment rather than simply reacting to them (Kilpatrick & Wirszup, 1969). Learners construct their own meanings from, and for, the ideas, objects and events which they experience and from the influences of their peers in the collaborative environment. It is now widely accepted that learning is best thought of as an active and productive social process on the part of the learner (AEC, 1990).

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Examples of such activity are given in the following observations from this study.

- *The students are fairly polite in discussion and take turns to talk but at times the 'all talk at once' mode occurs and seems just as effective.* (M1)
- *Data sharing occurs for some length of time, in quite an open, social environment. The class discusses the results and the teacher contrasts the class results with real world examples and with the individual student's results.* (M3)
- *The students are continually explaining, discussing, questioning, debating and conjecturing and good discussion accompanies development of the concepts.* (M4)
- *The students are in a very collaborative, open discussion type mode as they are working quietly and effectively through the activity.* (M5)

To have an inconsistency or "error" explained by a peer is far less paintul than have the teacher tell you that you are wrong (von Glasersfeld, 1993). Peer support and help is vital to the successful implementation of the collaborative environment and the students perceive such support as essential to their own and their groups progress. Evidence of this sort of support can be found in the next set of observations.

- *Students are no longer reluctant to support each other or question each others ideas.* (M1)
- *When the teacher analyses an incorrect student answer and uses this analysis to redirect the students focus the student can acknowledge that the original comment was an error yet still save face from the discussion.* (M2)
- *The students interact openly, correcting the teacher, correcting each other, contributing answers, providing answers the teacher does not have.* (M6)
- *They are quick to jump in to discussions to correct anyone.* (M6)

If peer teaching is to be used effectively, students must be able to work in groups while the teacher must be able to watch students learn and discover entirely on their own. There is little research to guide teachers in the selection of practices that are conducive to facilitating learning when control is assumed to be with the students rather than the teacher (Tobin, 1990). The teacher's role is to be a guide, and to support and suggest when questions arise, not tc answer the questions, but direct and guide the students (Mann, 1990).

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This concept also extends to the students as the observations below show.

- *If student opinions are important and valued then the teacher must follow up on student initiated thoughts and ideas.* (M1)
- *If students suggest correct alternative answers the teacher leaps on these and praises them to encourage these students.* (M6)

The work is not always collaborative nor interactive however as the following observation illustrates.

- *Some students zoom ahead and don't worry about their group and these people tend to tell the others the solutions rather than explain them.* (M3)

Negotiation:

An environment should be established in the classroom that places critical thinking at the heart of instruction. In an environment such as was established in this study everything stated or written or expressed in any way was open to analysis by all who are participating in the teaching and learning. Both teachers' and student's statements should be open to question, reaction, and elaboration from others in the classroom. The students had to be supportive, as suggested before, but they also needed to be able to develop ideas collaboratively and to be able to negotiate their own meanings intersubjectively. So the environment depends on all members of the class expressing genuine respect and support for one another's ideas (NCTM, 1989). Such support is often noted in this study as the following observations highlight.

- *In discussion the students were eagerly supporting each other, taking each others points up and developing them further until eventually they had all convinced themselves they were right.* (M3)
- *The students volunteer answers as each activity is discussed and the class makes comment whenever disagreement or confirmation is required. They discuss their methods, promote each others statements, put forward their points of view, discuss those of others, attempt to illustrate the meanings of new terms, support or correct each other as required and generally show a very collaborative and supportive environment.* (M4)

Students need to be given opportunities to make sense of what is learned by negotiating meaning (Tobin, 1990). Getting the right answer is important but it is not as important as working at a problem and investigating the possibilities. Group work involves asking questions, giving answers and getting answers (Linn & Burbules, 1993).

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Some of the observations below discuss questioning and answering.

- *The teacher positively guides students through tasks redirecting their thoughts on the activity which is better than just saying 'you're wrong, do it again'.* (M1)
- *When the teacher and the students are instructively working through answers the teacher must respond to multiple suggestions, exalting the most correct, acknowledging and praising the nearly correct and building on and redeveloping the incorrect.* (M4)
- *When questions cannot be resolved within the group then they are put to the whole class rather than being answered by the teacher.* (M6)

Explaining something to a peer usually leads to seeing things more clearly and often results in spotting inconsistencies in one's own thoughts. If students are able to explain something to a peer they boost their own confidence and may sometimes correct themselves in the process. When a small group explains its "solution" (irrespective of whether it happens to be viable or not) to the whole class, this provides a wonderful opportunity for learning (von Glasersfeld, 1993). Many opportunities exist in the collaborative, peer interactive environment for the students to explain things to each other as the following sample of observations illustrate.

- *Class discussion of solutions was based totally on student answers which involved collecting several responses to make the points clearer and determine their correctness by actually drawing them and testing them on the blackboard.* (M2)
- *One group has trouble resolving a set of questions but one of their number seems to convince and explain to the others eventually how to do it.* (M6)
- *When some strike conflict with their answers the students in those groups immediately go into 'teacher correct' mode and not just 'tell them' mode.* (M6)

The benefits of team-work and sharing lead to self regulation because it encourages the student to infer or develop a situation definition that will explain teacher or peer utterances (Ireland, 1986).

Consensus:

Teachers can foster a willingness to share by helping students explore a variety of ideas in reaching solutions and verifying their own thinking. This approach instils in students an understanding of the value of independent learning (NCTM, 1989).

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One of the observations from this study illustrates this point.

- *When the class shared a misconception the teacher made some notes alongside a student's solution to highlight the misconception at which point the students saw the problem and altered their answers.* (M4)

The teacher must encourage the students to develop a consensus when discussing in their groups, refraining from giving 'the' solution but rather building on the students work to develop concepts and understanding. Students should be encouraged to explain their reasoning in their own words and to listen to their peers and their teacher describe other strategies as this helps the students refine their thoughts and the language they use to express their thoughts (NCTM, 1989). These observations from this study illustrate this point.

- *Group consensus sometimes precludes the need or the desire for class consensus.* (M1)
- *The 'proximal zone' is open and peer teaching is in full swing when the students lead a class discussion of results and resolve each others mistakes.* (M1)

The teacher should never present a solution as the only one (von Glasersfeld, 1993). The following observation illustrates this point.

- *The teacher will often admit that the presented solution is not the only possible one and give examples which show the process but don't actually work.* (M3)

The role of the teacher during instruction includes encouraging the students to guess courageously, being willing to entertain suggestions from students and suspend judgment about their ideas, help students evaluate one another's suggestions and to critically reflect on them by anticipating objections and consequences (NCTM, 1989). The next observation from this study illustrates this point.

- *The teacher can agree with incorrect responses or at least not reject them, which prompts the students into responding or commenting thereby creating a need for correction or adjustment or explanation.* (M2)

Prior Knowledge:

Another important aspect of the social cultural framework is that of taking into account knowledge which the student already possesses or has experienced. Students bring to the classroom a wide range of backgrounds and experiences. To assist the learning process, teachers should try to build upon the students' previous experiences and draw on the students' varied backgrounds as they try to challenge and extend the existing ideas and knowledge that the students have (AEC, 1991).

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The learning experiences which are provided should build on the strengths which the students bring to the classroom (AEC, 1990). If teachers take time to discover why a student has made sense of the world in a particular way and what assumptions the students are working with, they will be in a better position to know what kinds of arguments and evidence will persuade the students (Burbules & Linn, 1991). The observations which follow illustrate some of the prior experience events which have been noted in this study.

- *The presence of prior concepts can restrict any change in beliefs as to what works and how it works.* (M1)
- *When the students cling to their past values and experiences the teacher must attempt to incorporate these as the new version of the concept is developed.* (M1)
- *A lot of prior knowledge was evident as student input was used to form and lead a discussion of the Metric system of units.* (M3)
- *The students commented that their knowledge of non-metrics was from their personal experiences. i.e. strong cultural influences/ experiences were evident.*(M3)
- *Mathematics is evident to the students in their non-school environment.* (M5)
- *The students explain their previous experiences with this activity when the teacher asks if they have done this before and one student notes the common term for a specific maths activity, which others agree with, showing their past experience.* (M5)
- *The teacher has the students check within their groups for experienced people. All have some but the students background has different procedures to what is now required.* (M6)
- *The teacher points out that there is a practical use of this exercise and the students add further to this with their own experiences.* (M6)

Mathematics learning is likely to be enhanced by activities which build upon and respect students' experiences. While students in any particular classroom will have much in common, they also bring to the classroom a wide range of different experiences which should be valued and accommodated (AEC, 1990). With such a wide range within the student group the teacher can almost always illustrate a concept with one of the students inputting an experience or relevant comment. Learning is a process of making sense of experience in terms of prior knowledge (Tobin, 1990). Much of what the teacher does in the class can relate to these past experiences as the observations which follow show.

- *The teacher compromises and incorporates some of the students background experience into the procedures.* (M2)
- *When students make comments about personal experiences to do with a topic 'colour' and 'reality' are added to the lesson.* (M4)

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- *Using student examples more often and observing the students when they give answers or discuss solutions can enhance the teachers understanding of the students conceptions.* (M6)

It is crucial for the teacher to get some idea of what concepts the students have and how they relate to them. Being aware of the students background serves to highlight to the teacher areas of weakness which might have otherwise escaped the teacher's attention. The teacher must also create situations where the students have the opportunity to experience the pleasure inherent in solving a problem, as successful thinking is far more important than "correct answers". 'At best, the teacher can orient the students' constructing in a fruitful direction, they can never force it' - Maria Montessori (in von Glasersfeld, 1993).

Prior knowledge can be gleaned by the teacher from the students in order to identify an approach which the teacher might then take to develop an activity or it might provide the basis for extending the students concepts beyond their present level. The students' background can even be the stepping stone to the next concept to be learned as the following two observations highlight.

- *A student asked a question about work we had not yet done and by addressing this within the context of known work the problem was placed within the students potential and a solution was negotiated.* (M2)
- *By surveying the class and monitoring student progress the teacher can determine which areas need a more detailed step-by-step procedure for the students to follow.* (M4)

Results:

As the researcher, Dennis would say that aspects from each framework of this study have had a positive impact on the students' learning. As the teacher he has seen much of the work being done in the groups operating in the collaborative peer interactive environment to enthuse him towards these approaches. Many times the work has been enhanced by drawing on the students for their experiences and by building on what they already know. Having the students discuss their ideas and develop consensus in their groups has improved their understandings and they seem to have fairly positive attitudes to their work, the class and the subject. By asking the students you get an honest 'users view' of how all of this is impacting on them.
The observations which follow show examples of such inquiries.

- *The teacher stops the students working and asks the class a question: "Does anybody feel that in today's lesson they got help from someone in their group which made them, the person who get the help, feel better, more confident, more able to do the work compared to if you hadn't got any help? Hand up if the answer to that question is Yes please.*
  Six students put up their hands. (M6) 21

- *Near the end of the lesson the teacher asked:*
  (i) how many students felt that they had no more knowledge about these ideas than that which they came to class with, felt that they were leaving without anything improved on what they did?
  None said yes;
  (ii) how many felt they were leaving more confused after today's lesson?
  Approximately one third of the class responded positively to this question;
  (iii) how many felt they were better off, had clarified some ideas today?
  Approximately two thirds of the class responded positively to this question of whom some said 'bits' were clearer. (M5)

Disconfirming evidence:

Action research, or research in the ethnographic style, necessitates a careful search for alternative or disconfirming evidence and the elimination of rival or alternative explanations, both in doing the research itself and in presenting the findings (Eisenhart, 1988). In the final analysis such disconfirming evidence is discussed in the context to which it applies but the following selection from this study is collected here to highlight this aspect of ethnographic research and to emphasise the events so identified. These examples of incidents noted during the fieldwork tend not to support the many theories permeating through this study nor the interpretations or generalisations which have been drawn from the data corpus.

- *In attempting to accommodate student ideas, which are poorly founded or are based on prior knowledge concepts only, an issue or new concept can become lost and unclear. Following student themes or ideas can also create confusion when dealing with a new concept beyond the immediate reach of some students.* (M1)
- *Sometimes the teacher answers his own question, gets the students to follow set steps to confirm a result, uses language and terminology without it having been previously explained or defined, and even goes through solutions giving the answers.* (M4)
- *The time pressure of completing a course does not always reflect favourably in the teacher's attitudes.* (M4)
- *The teacher may give a very dictatorial exposition (de-structivist vs con-structivist) using only the occasional student contributed idea.* (M5)

It could be construed that such evidence adds to this study much more than it threatens it, as it encourages the teacher-researcher to reflect on the pedagogical environment and this study's research questions. Searching for and finding such evidence focuses the awareness of the teacher-researcher to the true nature of the classroom interactions.

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As action research is reflective, the search for disconfirming evidence allows the researcher to maintain a true and correct focus on the objectives of this study and they allow the teacher to reflect on and build a better environment for student learning. In doing so this study is strengthened.

Reviewing the observational data.

Viewing the data presented in this article from a socio-cultural perspective highlights the importance of the learners developing the social norms for use in the environment (Rogoff, 1990), reflecting on their work, collaborating with peers, negotiating meaning through discussion (Huber 1990; von Glasersfeld, 1991; Lochhead, 1991), arriving at consensus and accounting for the background knowledge each student brings to class (Baroody & Ginsburg, 1991; Cobb et al., 1991).

The observations revealed the social outcomes evident among the students, for example listening, caring for the progress of others, negotiating explanations and solutions into a group consensus, peer teaching, providing help and guidance where needed (Rogoff, 1990), feeling less threatened through the sharing of problems and sharing marks based on group assessment (Slavin, 1986). We can also see from the observations that using peer interaction reduced the demands on the teacher and allowed that 'resource' to be directed to areas of need more frequently. One of the most valued outcomes was that students often saw things more clearly for themselves and could even spot inconsistencies in their own thoughts by explaining something to their peers. This also led to considerable discourse as students felt free to indicate whether they agreed with, disagreed with, or simply didn't understand the explanations of others (Wood et al., in press). Such discourse has been highlighted by social constructivism as central to the effective development of the learning situation and was indeed one of the facets of the constructivist perspective that the authors could see functioning within this study.

Findings: the evaluation of the classroom environment by the students using the MCI

Interpretive or action research such as was carried out in this study is reflective and as such tends to be cyclic in its methodological execution (McNiff, 1988; Hall, 1994). Observations are made in an attempt to provide information regarding the questions posed, material such as tests, surveys and questionnaires are collected to supplement the observations, then an analysis is carried out on all of the collected data and in this study this enabled a "correction" to take place to enhance the environment and then the process started all over again through further observation.

The cycle described above was fully operational every four weeks or so throughout this study. The field notes and audio recordings which generated the weekly summaries tended to reflect set patterns in the classroom routine and set trends in the behaviour of the teacher and students working in the collaborative, peer interactive environment. For the teacher who is also the researcher these trends and patterns are sometimes difficult to see.

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Making the familiar strange is a necessary condition to effective observation and the way this was overcome in this study was to rely on the students' opinions about the environment (Gallagher, 1984). Their opinions had primacy in the collected observations as it was considered that the environment had been implemented for their benefit, in terms of creating an effective learning climate, and so if the students had opinions which required an alteration in the way the environment was structured or was operating then changes were made to affect such alterations.

The authors consider this process to be one of the unique features of this study. It was often the case that the students views and opinions made what was familiar to the teacher suddenly seem strange. The process also had the effect of altering the power relations within the classroom as the use of student feedback to control the ongoing modification of the learning environment, making it adaptive to their needs, empowered the students to at least equal status with, and sometimes beyond, that of the teacher.

As an example of the student input into the analysis of the environment the following set of findings are presented. They represent the classroom environment measures covering the first six months of this study and were obtained using the MCI learning environment instrument (Fraser & Fisher, 1983). The full analysis of the year long study's findings from the MCI learning environment instrument includes individual student surveys, group based surveys and class based surveys. The results presented here are the more general class based findings from the first semester which contained four such surveys.

TABLE 1

Results of the My Class Inventory Survey Number 1

	Satisfaction	Friction	Competitiveness	Difficulty	Cohesiveness
Actual	12.583	7.083	10.153	6.944	9.792
Preferred	14.639	5.583	7.056	6.375	12.736

Table 1 above illustrates the class responses to the first MCI survey conducted after the class had been together for only 9 lessons. On all scales the students sought improvements in the environment. In terms of the measures the students indicated that they are highly satisfied and that the difficulty level of the work seems quite low. In particular they required improvement in the level of cohesiveness and preferred less competitiveness. Each of these results suggested that at this stage the collaborative processes had not yet fully developed. A graphical representation of the first survey is shown in Figure 1 on the next page.

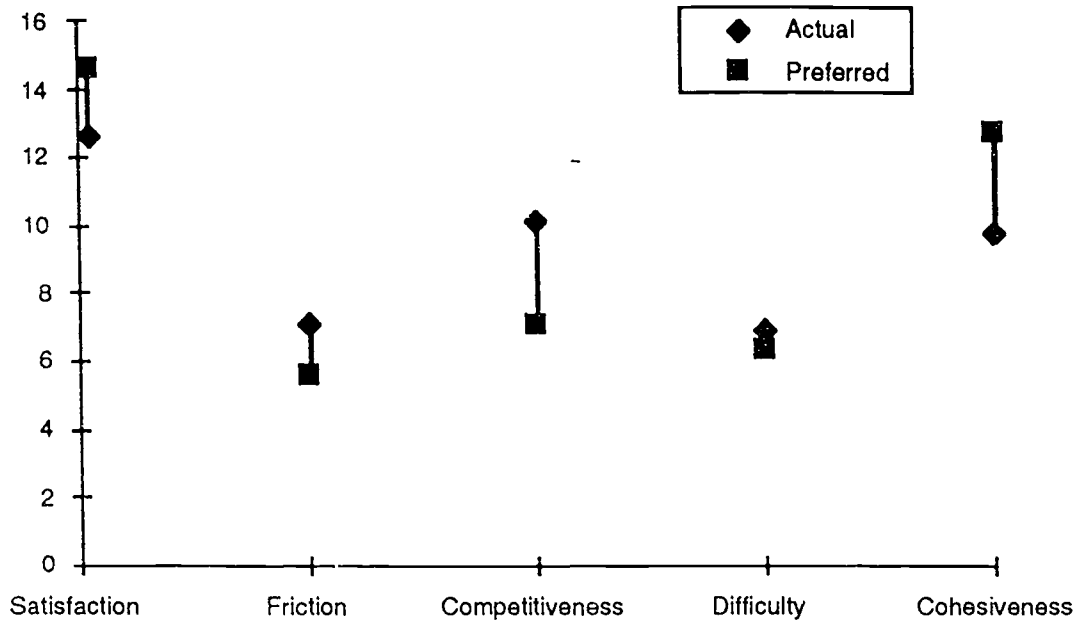

Figure 1

Results of the My Class Inventory Survey Number 1

The second MCI survey was conducted after the class had been together for nearly six weeks. Four of the scales showed improvements in the environment but on all scales the students sought further improvements. In particular they required improvement in the level of satisfaction, which was the one scale to fail to improve, although the measure of the actual level of satisfaction is still very high. In his review of this survey with the students Dennis commented that these were near perfect results and certainly showed an improvement in the right direction from the first survey. The third MCI survey was conducted in the second school term after the class had been together for twelve weeks. This survey reflected an increased level of friction, a decreased level of cohesiveness and the increasing level of difficulty of the topics being studied as the course incorporated less review work and more of the high school curriculum. Improvements in the environment were made on the scales of satisfaction and competitiveness.

TABLE 2

Results of the My Class Inventory Survey Number 4

	Satisfaction	Friction	Competitiveness	Difficulty	Cohesiveness
Actual	12.194	7.028	9.056	7.972	9.597
Preferred	14.417	5.306	7.500	6.806	11.778

Table 2 above illustrates the class responses to the fourth MCI survey conducted after the class had been together for nearly seventeen weeks. It was administered a few days after the students had completed their major semester exams and prior to their receiving their grades for those exams.

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The survey reported a favourable reduction in the level of friction but the students were less satisfied, working less cohesively and, had experienced more difficulty in the topics (and perhaps in the exam) and more competitiveness within their groups. The students were aware that their exam results were going to determine their class allocation for next term. Overall the results of this survey were very similar to those from the previous survey with. A graphical representation of the fourth survey is show in Figure 2 below.

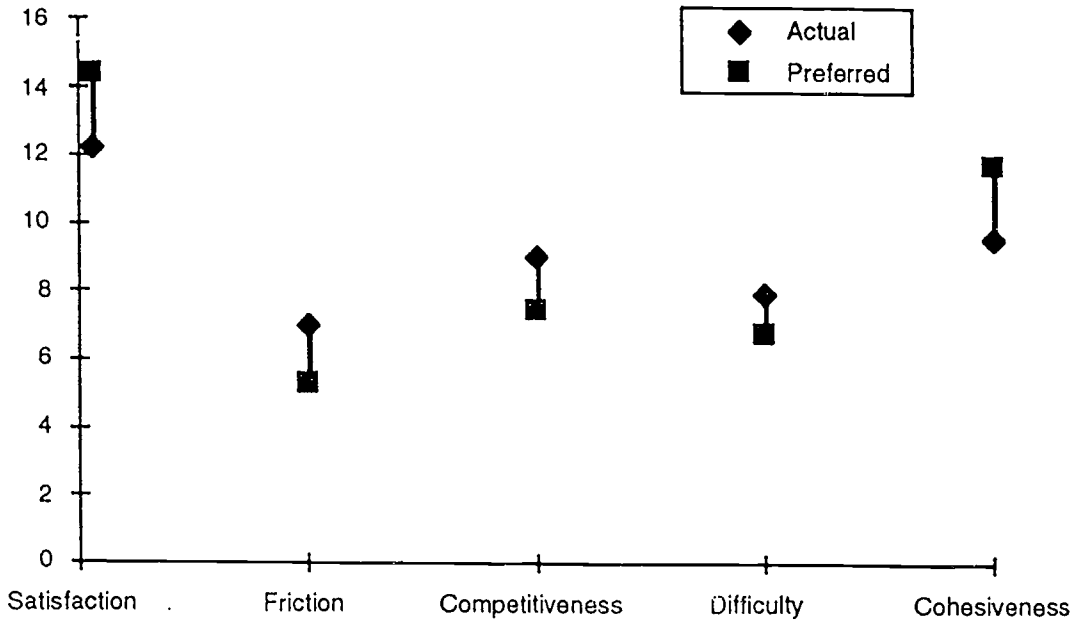

Figure 2

Results of the My Class Inventory Survey Number 4

Examining the figures for the students 'actual' measures on each of the scales for MCIs 1 through 4 shows how the satisfaction scale measure went down then up then down again, finally finishing up lower than it started whereas for the difficulty scale the measure went down initially then during second term it went up and then up again, finishing higher than it started. Examining the figures for the students 'preferred' measures on each of the scales show that the students ended the semester preferring a lower level of satisfaction, a higher level of competitiveness, more difficult work and less cohesiveness than when they first started. Such figures may indicate a degree of acceptance of the features of the environment and reflect their perception that things are not going to change all that much or all that quickly as perhaps they would prefer.

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Reviewing the MCI data.

In attempting to monitor the students' attitudes towards their changing classroom environment, this study took the somewhat unique focus of placing the students in a position of control and in attempting to execute changes to facilitate the kind of environment the students preferred. The data from the MCI surveys reviewed in this paper show that the students initially had opinions about their preferred learning environment which were very compatible with the actual environment, but that they still had even higher expectations as to what it could achieve. The satisfaction scale showed improvement over the first three measures but this was lost by the fourth measure. The students were very demanding in their preferences on this scale but the measure did reflect a consistently high result in terms of their actual level of satisfaction. The friction scale fluctuated between consecutive measures from improvement then decline and then improvement again. The friction measure reflected of the level of negotiation and consensus building that was occurring. The competitiveness scale showed constant improvement. The students did acquire improved levels of collaboration and hence the environment reflected this in the constant decline in competitiveness. The difficulty scale showed initial improvement but then the work became more and more challenging over the next two measures reflecting the difficulty within the mathematics course. Finally the cohesiveness scale showed considerable initial improvement but then this steadily declined over the next two measures although it did show that the cohesiveness scale had improved over the full semester.

Over the course of the surveys the impact of many facets of the developing environment could be seen to interplay on the reactions and opinions the students registered as to the environment. Facets such as the increasing level of difficulty of the course work, the students development of interpersonal social skills and collaborative work techniques and the effects of external examination which influenced the students acceptance of a greater level of competitiveness as the semester progressed. Coupled with the observational data, the MCI data encourage the authors to highly recommend the use of an environment such as that described in this paper and to also encourage teachers to monitor their teaching learning environment for the students input. This certainly led us to develop a more effective classroom.

Findings: peer evaluation or 'buddy' reports

Another unique feature from this study involved the use of the students as observers of each other within the collaborative, peer interactive learning environment. Monitoring can be done using a student as an observer or by the group itself (Schultz, 1990, p. 44). The opportunity for this student based observation came about as a result half of the class going on camp during week seven and the other half going during week eight. The groups were restructured as follows during the first camp week and the reverse procedure, (in brackets), applied during the second camp week. The groups which usually had four (three) members, each lost one member and the groups which usually had three (four) members, each lost two (three) members.

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Therefore, the individuals left over were appointed by the teacher to fill the one gap in each of the remaining groups. On appointment, the individual student was advised of the teacher's desire that they observe the group they had been appointed to and at the week's end report on the collaborative behaviours of the other students they were joining in with. Towards the end of each week it became clear to the teacher that the students were aware of what was going on and so the reports which the 'visiting' students wrote about their respective 'host' groups became known in the class as the 'buddy' reports. One problem remained however. Each of the six 'buddies' had not themselves been observed or commented on and so, during the next two weeks it was organised for observations to be made of these students by their peers. As a result a 'buddy' report was collected on each student.

The following extracts (*in italics*) from the data corpus represent highlights of the 'buddy' reports as presented to the students' parents during one of the parent information evenings that occurred during this study. The fact that these were peer evaluations was clearly explained to the parents and the reports had a very favourable reception. The variations in the extracts are the result of the students differing reporting styles which have not been altered or edited.

Jenny: All homework has been done and looks all correct. A bit messy though. Betty: Did not have book. Not sure if homework is done. Combined: They worked together extremely well. Both came up with good points today in Maths when we were doing exercises. Overall ; They work together extremely well and get their work done quickly. Cathy was just acting nice because I was there. She isn't usually all that nice. She didn't do all that much and she wasn't much help.
Amanda is very smart but just not as smart as Denise. Amanda depends much more on the group than Denise does. Sometimes it looks like she struggles a bit but other than that she seems to be doing well. Emma works very well with her group, but sometimes is quiet and won't contribute. Emma complains that Denise does 'solo' work and doesn't contribute the their group.

Faye is a kind person. In our maths group she always shares her answers and is willing to listen to the other girls. Gwen is a shy, quiet person. She works hard on her answers and problems when she has answered all of the questions she waits for another member of our group to give an answer first before she discusses hers. Maybe she is afraid of speaking up first because of her shyness. Hillary is quite humorous. She works out her answers very quickly but is very reluctant to participate. She is unwilling to discuss and share. But I like her!!. Isobel is a hard working student. She concentrated on what to learn and when she understood she made sure everyone else understood and then went on with the activities. I think she puts in a lot of effort, compared to some other students. On top of all that Isobel manages to have a smile on her face all day.

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Kerry is sensible, tries hard and does her homework. Unfortunately Kerry sometimes doesn't understand things and gets very confused. Kerry is eager to learn and can get the groups marks to a higher position. Louise needs someone in her group that has a good knowledge of maths and who understands it and can be good at explaining questions.
Mary is very bright but lazy and doesn't do her homework but in class she is quite good and gets most of the questions right quickly.
Yvonne is a good worker who really tries hard but loses her concentration easily. Overall she is a good worker.

Narissa is not used to working in a group and doesn't check answers with the other members of the group. Penny doesn't understand work very well and needs it to be explained a few times. Penny is good at mental. I think Robyn is fairly valuable to the groups discussion. She will not butt in when everyone else is talking but wait to the end. She seems to enjoy the people in her group and she is fairly friendly.
Trudy will work until she comes across something she doesn't understand then she'll ask the group what they think about it. Wendy works, as a group, very well. When she thought differently to the group she would bring it up and explained it to the group so they would understand and usually she was right. She was quite quiet but she did get the group to listen.

Reviewing the 'buddy' reports.

These 'buddy' reports were one of the unique features presented in this paper. These reports became a very useful and enlightening facet of this study with many of the student observations giving the teacher (not to mention the parents !) greater insight into the functioning of the implemented environment. We would strongly recommend such a feature be a part of any collaborative environment provided that such data was freely available to all members of the class and that it was seen as being used to improve the environment for the students benefit. Teachers working in a collaborative environment could utilise an Envoy (Larsen & Pfitzner, 1993) technique to achieve the same outcome as the 'buddy' reports.

Conclusion

This study implemented a collaborative, peer interactive learning environment to determine how such an environment could function within the normal routine of school life and what the students thought of working in such an environment. Situating the activities in a socially aware setting highlighted the value of the students socio-cultural experiences to the learning of mathematics, and adopting a collaborative group work approach placed this study in a still rare setting (Graves, 1992, p. 63) which facilitated negotiation, consensus and the development of appropriate social norms based on the natural learning habits of students (LaCombe, 1992, p. 7; Higgins, 1992, p. 2).

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Vygotskian theory supported the use of peer interaction, and constructivist theory encouraged the adoption of a more student-centred environment where prior knowledge and background experiences played an important role.

Some see the latest trend towards social constructivism as a natural progression of this paradigm (Ernest, 1991) and one which complements the growing interest in socio-culturalism (Cobb, 1994). Constructivism has a very large following in mathematics education and has now spread through the national mathematics education policies of several Western countries (AEC, 1990; NCTM, 1989; Cockcroft, 1982). It comes in many guises (Good, 1993) and this apparent lack of consistency has brought upon it much criticism of late (Lerman, in preparation).

Whether one supports one or more of the various forms of constructivism or not, there are several benefits to be had for the students from adopting the constructivist perspective within one's teaching approach. These include benefits which stem from recognition of the students' prior or background knowledge, enhancing collaboration and interaction, which Vygotsky encouraged as a means to enhance development through instruction (Rogoff, 1990; Moll, 1990), enhancing negotiation and consensus within the classroom through the increased use of discussion aimed at achieving intersubjectivity (Wertsch, 1985), and developing the students social skills. Indeed these benefits are not so much the result of a social constructivist approach as they are simply a recognition of the importance of the role of the social environment in the learning process, something supported by both Vygotsky, contemporary socio-culturalists and latter day social constructivists.

One of the most important indices of the plausibility and fruitfulness of the Vygotskian school of thought is the fact that their experimental research and theoretical hypotheses, though developed simultaneously, led not only to consonant but to fully unified findings (Vygotsky, 1987, p. 240). Much of what they achieved resulted from their pursuit of classroom-based research taking the socio-cultural impact of the students' everyday experiences into account in the development of their theories and hypotheses. Vygotsky's basic conclusion of his theoretical discussions was that the actual movement in the development of the student's thinking occurs not from the individual to some state of socialisation but from the social to the individual. This was also the basic conclusion of his empirical work (Vygotsky, 1987, p. 74-76).

As the authors review their findings they are acutely aware of the very strong influence that Vygotsky's socio-culturally based theories have had on their interpretations throughout this study. Influences in the way they formulated and designed this study and the execution of the implementation of a collaborative, peer interactive learning environment along with a strong influence in the way they interpreted and analysed the data corpus. In addition to Vygotsky, they are aware of the impact of contemporary socio-cultural theory in these same facets of our work, and also of the influence that social constructivism had on their approach.

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Adopting the socio-cultural focus as was preferred by Vygotsky (Lerman, in preparation; Wertsch, 1991) made it easy to facilitate the exchange that occurs between spontaneous or 'everyday' concepts and scientific concepts (van der Veer & Valsiner, 1991). The 'everyday' concepts arise from the social and cultural experiences of the students and mediates the acquisition of the scientific concepts (Moll, 1990). Flexibility was the key to the development of the concepts in any one topic because it was very easy to teach to some 'average' student and thereby quickly go beyond the level at which some of the students are comfortable working at. The mathematics programme which the students were exposed to unfolded as the year progressed and to some extent it was taken for granted that the functions that were maturing in each student's zone of proximal development were those of the course curriculum being addressed at the same point in time. Of course such was not always the case due to the wide disparity between the personal zones of the twenty or so individual students studied.

By the end of this study the classroom operated on a basis where the students were more active participants in their own mathematics learning and culture than they had been at the beginning of the year. Working on only partially mastered tasks and doing so successfully because of the help of others became normal practice in the classroom and helped develop the continuous feature of operating with a 'classwide' zone of proximal development (Hedegaard, 1990). Findings also demonstrate that Dennis had progressed towards a more socio-cultural approach in his teaching, convinced that the future education of his students would be based upon the principle of teaching them about learning to learn in a socially diverse and culturally mixed global community. Outcomes for Dennis included the further development of skills such as facilitating discussion within the student groups, question redirection and explanation development, utilising student prior knowledge and monitoring the classroom environment to ensure the students' needs in this regard were being addressed.

Future research.

Several international studies and reports call for an increase in the use of collaborative environments for the teaching and learning of mathematics along with a greater awareness of the role of the social and cultural environment on the learning situation (AEC, 1990, p. 6-7; NCTM, 1989; Cockcroft, 1982; Bishop & Nickson, 1983; Wilson, 1981). The research reported here is significant in that it examines the effect of a collaborative peer interactive environment on the attitudes of the students in a typical Australian mathematics classroom. The importance of the cultural impact upon the classroom, which was emphasised by Vygotsky in his own research (Vygotsky, 1987), is one focus of the recently published National Statement on Mathematics for Australian Schools (AEC, 1990, p. 6-7).

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Further research is needed on a wide range of classroom implementation issues to provide teachers with adequate principles and guide-lines to facilitate the appropriate use of collaborative small-group instruction in mathematics (Mulryan, 1992, p. 262). If, as Vygotsky (1962) argues, collaboratively achieved success lies at the heart of learning and development, then we need to ensure that optimal conditions exist in the classroom setting (Bennett & Dunne, 1991, p. 115). Research such as this has a message for teachers and researchers, especially those with a focus on Vygotskian perspectives (Moll, 1990, p. 2; Pontecorvo, 1990, p. 3; Vasta et al., 1992), and it is hoped that our findings will encourage others to duplicate this implementation and develop the practices and outcomes in a manner appropriate to their own socio-cultural conditions (Bassey, 1986, p. 21). Facilitating peer interactions by grouping different ability students may be insufficient in promoting learning. This study sought to give more attention to the process of collaboration and the specific conditions that may help develop such environments (Moll, 1990, p. 18).

The situations that a teacher deals with everyday are complex and therefore the focus of research must swing away from the laboratory and into the classroom (Toumasis, 1990, p. 36). Perhaps the best any socio-cultural position can achieve, be it Vygotskian, constructivist or more purely socio-culturalist, is to suggest to the teacher that they be aware of the socio-cultural influences that affect their teaching learning environment and that they try to ensure that they gain for their students the maximum benefit from their awareness.

From their experiences, mathematics teachers know that despite all the research, they remain encumbered in their daily struggle with the problems which appear in the typical mathematics classroom. What the teacher needs and what we hope this study provides, are simple, realistic ideas which spring from the classroom. Specific techniques and procedures which can be used without special instruments or special preparations and sophisticated plans. To the classroom teacher, realism is what stems from raw, daily, school routine (Toumasis, 1990, p. 36).

Creating an environment in the classroom such as that developed in this study allows the teacher and the students to all actively engage in the teaching and learning of mathematics. We can't think of a better place in which to teach.

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